Very Fine-Line Lithography for Extreme Ultraviolet and Soft X-Ray Optics

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The Very Fine-Line Grating Lithography Project is a phase II Small Business Innovation Research contract directed toward the development of technology to lithograph 0.1-micron- (1,000-angstrom-) period diffraction-grating patterns. Gratings with a period this small have 10,000 lines per millimeter in their pattern and cannot currently be produced in large areas at a reasonable cost. The goal of the research is to develop technology that can be used to produce large-scale (greater than 10 square centimeters) area patterns affordably. Patterns produced by this technology would be used as the starting point for production of extreme ultraviolet and x-ray diffraction gratings for NASA space science missions and such commercial applications as microscopy calibration gratings and grids, fine-scale positioner grids and gratings, and wire-grid polarizers.

Achromatic holographic lithography, a basic optical technique, has been demonstrated previously, but is currently little more than a laboratory curiosity. Earlier demonstrations using this technique have produced a few square millimeters of grating pattern per exposure. The cost of these experiments is prohibitive, thus precluding commercialization or practical application. One reason for their impracticality is their use of deep ultraviolet and x-ray radiation sources, which are expensive to operate and/or are poorly suited to the optical requirements of the technique, but are required to use radiation with a wavelength smaller than 200 nanometers.

The purpose of the Very Fine-Line Grating Lithography effort is to explore the possibility of developing achromatic holographic lithography into a practical technology. Phase I work led to a conceptual design for a practical lithography system. During phase II, MOXTEK, Inc., will build a system based on this concept and demonstrate its feasibility. (MOXTEK is currently building a prototype lithography system.) The deliverable of the phase II program will be a set of optical quality substrates to be patterned using achromatic holography (a 0.097-micron pitch grating is expected).

Following the successful completion of the research, MOXTEK expects to use very fine-line gratings as integral components of small, portable, soft x-ray fluorescence devices. Very fine-line gratings would critically enhance such devices, making it easier to produce high-performance instruments. Additional uses of the lithography technique include light polarizers or reflective beam-splitters, which are indicative of the potentially large commercial market applications.

Wire-grid polarizers are common in such long-wavelength applications as millimeter waves and the infrared, where they can even be produced by wrapping wire strands over a form. With visible light, the pitch of the wire grid must be less than 0.12 micron—a requirement that can be met with this new lithography technique. However, since the grating period must be about one-sixth of the shortest operating wavelength to achieve high extinction ratios to completely cover the entire visible spectrum, a pitch of about 0.08 micron is actually required, which also appears to be achievable with the system being developed.

The development of high-performance optics for use in the extreme ultraviolet and soft x-ray regions of the electromagnetic spectrum is technologically difficult. Reflecting optics, often based on multilayer reflection, are currently the only practical optic for most applications. Recent advances in achromatic lithography offer the potential for a commercially viable technique with application to NASA space science missions, as well as the commercial instrumentation and sensing industries. The successful completion of this Small Business Innovation Research will be an important step toward that end.

Hansen, D.P.; Reyes-Mena, A.; Colton, J.; Knight, L.; and Allred, D.D. 1992. Multilayer Phase-Diffraction Gratings Modeled as a Structure in Three Dimensions. Society of Photo-optical Engineers, 1742.

Hansen, D.P.; Reyes-Mena, A., and Knight, L. February 1993. Diffractive X-Ray Optics. Soft X-Rays in the 21st Century, Provo, Utah.

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